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Recycle of metals for end-of-life vehicles (ELVs) and relation to Kyoto protocol

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ABSTRACT

As the world's energy resources are rapidly being depleted, decreasing the use of raw materials and recovery and recycling of metals are currently considered as the most rational and essential methods. In Turkey, transportation needs increasing in parallel to urbanization cause an increase in number of vehicles. Greenhouse gas emissions resulting from transportation make up approximately 16% of Turkey's overall greenhouse gas emissions. Turkey signed in the Kyoto protocol on 26 February 2009, and therefore accepted commitments such as developing and implementing policies to prevent climate change and taking measures to increase energy efficiency and energy saving. In this context, such a regulation of banning from traffic those vehicles having old technology and high CO_2 emissions would enable not only recovery of CO_2 but also compliance to ecological principles of recycling of metals such as aluminum and iron and steel found in the end-of-life vehicles (ELVs). Also, the energy sector will make benefit by the recovery and recycling of raw materials. An end-of-life vehicle is composed approximately of 68% iron/steel, 22% aluminum and 8% other metals. In Turkey, number of vehicles of old technology (Pre-Euro) is around 3 millions. In case of banning these vehicles from traffic and recovering all the metals, a significant amount of raw material and energy benefit can be achieved. With such benefits, both of the targets in the recently signed protocol, reduction of emissions and energy recovery can be achieved concurrently and in a short time.

Contents

1. Introduction

Energy is essential to economic and social development and improved quality of life in Turkey as in other countries. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption in the country [1]. Turkey has signed the Kyoto protocol in February 2009 and committed to fulfill the requirements of the new regulations starting after 2012. Some of these regulations are carried into effect for reducing the industrial pollution and the emission of greenhouse gases, as well as for using less energy for heating and transportation. Especially in metropolitan cities, vehicles have a significant effect on air pollution. Thus one of the easy solutions in order to control air pollution is reducing the CO_2 emission caused by transportation vehicles. Already, throughout the world all sectors except for the transportation sector tend towards decreasing the CO_2 emissions in their products and their activities. Therefore, every precautionary measure, which will be taken in the transportation sector, is of great value. The aim should be attaining an environmental approach to production without decreasing the economical growth [2,3].

Turkey has signed the United Nations Framework Convention on Climate Change in May 2004. The Turkish Parliamentary General

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Table 1
Materials used in scrap vehicle.

Materials used in scrap	Amount in a car[a] (kg)
Iron–steel	710
Rubber	90
Plastic	60
Glass	30
Aluminum	22
Lead	10
Zinc, copper, nickel	11
Other metals	11
Others	56

Source: Ref. [7].
[a] A car's average weight was taken as 1050 kg.

Assembly approved the draft law regarding the participation in the Kyoto protocol for controlling the green gas emission on February 26th, 2009 and the agreement was sent to the United Nations General Secretary. Turkey has initiated the relevant energy efficiency, air pollution and emission control issues even though the responsibility, which was undertaken by the negotiation was a requirement to decrease the greenhouse gases after the year 2012. According to the Ministry of Energy and Natural Resources modeling studies, in 2020 the greenhouse emission was calculated to be 687 million tonnes and by minimizing the energy consumption, this value can be reduced about 11% [4,5].

Similar to what the Kyoto protocol targets in terms of achievement in the transportation sector, the primary objective of the EU countries is the 95% recovery of car parts and materials (Table 1). For this purpose 2000/53/EC and 2002/95/EC (ELV Directives) like directives came into effect. In accordance with these actions, technologies that are required for economically adapting the use of metal and plastic materials in vehicles are targeted. The need for raw materials and the accompanying environmental problems will be minimized by recycling of scrap vehicles [6]. Iron–steel, plastic, aluminum (Al), glass and similar materials can be found in a car and recycling these materials will prevent the depletion of natural resources and will be a great contribution to the countries economy [7]. The basic principle of recycling scrap vehicles is using these vehicles as spare parts and if this is not possible then recycling these vehicles themselves should be aimed. Another issue is the prevention of environmental pollution in terms of solid waste. Especially for countries that do not have enough space for solid waste disposal on a regular basis, the reduction of the volume and the amount of solid waste is a huge benefit.

On the other hand, Turkey, with its young population and growing energy demand per person, its fast growing urbanization, and its economic development, has been one of the fast growing power markets of the world for last two decades. It is expected that demand for electric energy in Turkey will be 2.09 billion GJ by the year 2020 [8].

Iron–steel industry is the largest industrial energy consumer with approximately 19% of the total share. In this sector, energy consumption has the biggest cost with 27–33% share of energy [9]. Two main process routes for steel making can be distinguished, the classic blast furnace/basic oxygen furnaces route and direct melting of the scrap (that is electric arc furnace). In European Union, about two-third (∼61%) of crude steel is produced via the blast furnace route (primary steel), and about one-third (∼39%) is produced in electric arc furnaces (secondary steel) by melting the scrap. In the primary iron–steel production, pig iron is produced and converted to steel in integrated facilities by processing the iron ore in blast furnaces. The direct smelting of iron-containing scrap is usually performed in electric arc furnaces. The integrated steelwork process needs energy of about 19.8 GJ and a CO_2 emission of about 2.1 tonnes occurs, however the direct melting of steel using electric arc furnace needs energy of about 2.5 GJ and a CO_2 emission of about 41 tonnes occurs per tonne of steel [10].

Also the situation is not different for aluminum. Especially, in primary production (from the ore) the consumption of energy and the CO_2 emissions cannot be underestimated. To produce only 1 tonne of aluminum, the consumption of energy is about 93.3 GJ and the emission of CO_2 is about 10 tonnes. The energy gain in the secondary smelting of Al is equal to 97% of producing Al from raw materials and this prevents the industry to use the natural resources of the country [11,12]. In this study, the energy consumption and the emissions of CO_2 were calculated for the recycling of a scrap car in the national car park. The values were compared with the primary production and the net earning of the energy and the CO_2 emission were determined.

2. Materials and methods

Today 2,721,250 cars are completely worn-out in Turkey. This value may reach 3,000,000 if we add the other type of vehicles like the trucks, the motorcycles and similar vehicles [13]. We regarded that the cars manufactured before 1990 to have approximately 50 kg of Al and also about 62 kg of Al to be present on average in a 1990–1995 model car. 100% of Al was assumed to be recycled in a 1050 kg car. In addition, it was considered that on average 700 kg of iron and steel can be found in cars which were manufactured before 1990 and as high as 95% of this scrap can be recycled. The ratios of used iron–steel and aluminum have been noted in the calculations with respect to the model of the vehicle. The energy use and the CO_2 emission values which are used in the calculations are comparatively given Table 2 for the production of aluminum and iron–steel form scrap and ore.

3. Results and discussion

Greenhouse gas emissions in Turkey can be calculated for different sectors. Specifically, the energy sector, the waste sector and the agricultural sector are at the first three in terms of higher emissions. With 78% share, the energy sector has the most greenhouse gas emissions among these sectors [13]. Turkey has signed the Kyoto protocol and hence the necessary precautions that need to be taken to reduce the green gas emissions will be taken by every sector. The first step that needs to be taken in the transport sector should be that new cars which have low emission values should be used rather than the old cars. In this context, when compared with 1990 and older model gasoline run cars, in the 2009 model cars, the emission of CO_2 is reduced by 25%. Reductions in the emissions of other

Table 2
Comparative values of energy use and CO_2 emissions of recycling scrap metal and production from ore in both aluminum and iron–steel sectors.

	Aluminum industry		Iron–steel industry	
	Scrap	Ore	Scrap	Ore
Energy consumption (GJ/tonnes metal)	7.1	0.5	2.5	0.41
CO_2 emission (tonnes/tonnes metal)	93.3	10	19.8	2.1

Source: Ref. [10].

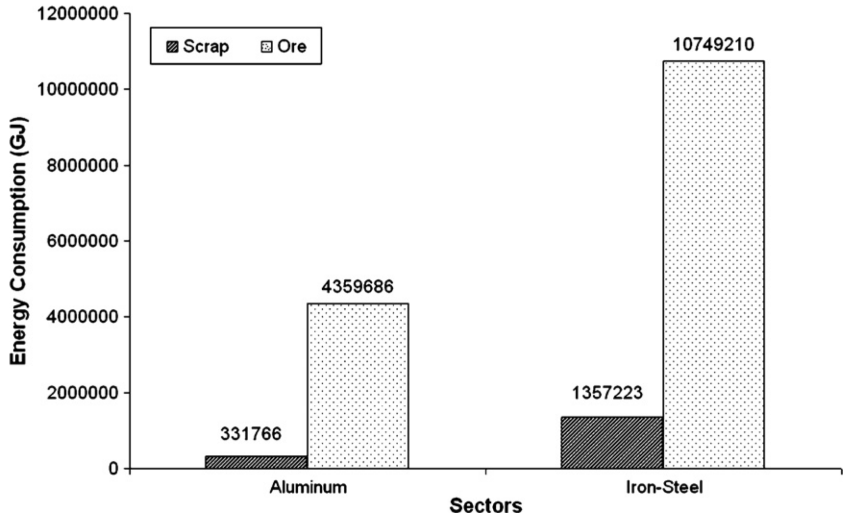


Fig. 1. Energy consumption for the ore and the scrap metal recycling for 30% of the scrap vehicles in the national car park.

gases (like CH_4, N_2O) are over 90%. It is obvious that recycling of high emission old cars will be a successful choice of solution.

Recycling of the steel and the aluminum in vehicles is a solution commonly used in the EU countries. The energy consumed during primary production from the raw material is very high. In production from scrap (secondary production), the energy gains are between 80 and 97% for different sectors. Naturally the CO_2 emissions during production should be taken into consideration as a parameter. In this study, both of these parameters for obtaining metal from scrap vehicle were taken into account and the findings are interpreted.

In Turkey 272,125 million units of automobiles are over the age of 16. Approximately 155,000 tonnes of aluminum and about 1.8 million tonnes of iron–steel scrap can be obtained from them. It is accepted that 95% of the iron–steel and also 100% of the aluminum can be scrapped from a scrap vehicle. These figures are compared with the existing integrated iron–steel and aluminum production values of 2008 in Turkey. These values are equal to 24.32% of the raw steel production and 2.5 times of the primary aluminum production (Erdemir Co. and other integrated production values of iron–steel is 7.03 million tonnes; Seydisehir Aluminum Co. production values for aluminum is 60,000 tonnes) [14,15].

The energy consumption for iron–steel and aluminum production from the ore is shown in Fig. 1. Likewise, the energy consumption of recycling 30% of the scrap cars in the national car park is given. The difference between the ore and the scrap is 12 times in aluminum and 8 times in iron–steel production as it can be seen in Fig. 1. In this case, 92.4% and 87.4% of energy recovery can be achieved for aluminum and iron–steel, respectively.

Similar investigation as for the energy consumption is made for the CO_2 emissions. 30% recovery of the scrap vehicles can reduce CO_2 emission by 443.912 tonnes (Fig. 2). The reduction of emission in the iron–steel industry may reach as high as 1.216.529 tonnes. The reduction means 95% and 80.5% less CO_2 release into the air for Al and iron–steel, respectively. This benefit is especially important for countries such as Turkey which tries to reduce CO_2 emissions in transportation and industry sectors.

Either way, remarkable energy gain and decrease in CO_2 emissions will be achieved by only recycling 30% of the scrap vehicles. In the calculations for the scrap vehicles, different amount of aluminum and iron–steel used from different vehicle models were taken into consideration The car models that were produced before 1990 have approximately 50 kg of aluminum and even if 50–100% of these could be recycled and the CO_2 emissions will go lower and

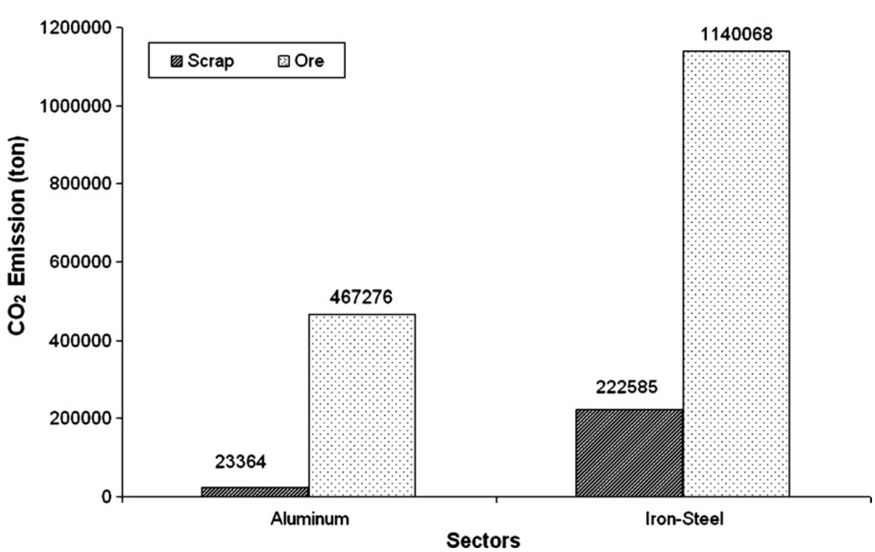


Fig. 2. CO_2 emissions for the ore and the scrap metal recycling for 30% of the scrap vehicles in the national car park.

Table 3
Energy consumption and CO_2 emissions for recycling of the end-life vehicles instead of using the ore in the aluminum and the iron–steel industries.

	Aluminum industry		Iron–steel industry	
	Energy consumption (GJ)	CO_2 emission (tonnes)	Energy consumption (GJ)	CO_2 emission (tonnes)
Scrap recycling				
30%				
Ore	4,359,686	467,276	1,0749,210	1,140,068
Scrap	331,766	23,364	1,357,223	222,585
Earnings	4,027,920	443,912	9,391,986	917,483
50%				
Ore	7,266,144	778,794	1,7915,349	1,900,113
Scrap	552,943	38,940	2,262,039	370,974
Earnings	6,713,200	739,854	15,653,310	1,529,138
100%				
Ore	14,532,288	1,557,587	35,830,699	3,800,226
Scrap	1,105,887	77,879	4,524,078	741,949
Earnings	13,426,401	1,479,708	31,306,621	3,058,277

the energy gain will be higher. In this way, approximately 100 kg of iron, steel and copper materials can be preserved because about 50 kg of Al is present in older cars. In newly produced vehicles, this aluminum amount may reach up to 150 kg. Depending on these foresights the purposed net earnings are given in Table 3.

4. Conclusions

Aside for the production stage and the use of vehicles, the material and the waste economy system must be established and compatible with most countries as accepted by the world. The main principle of the future production and consumption patterns is not to create any waste or use recycled wastes into the economy as much as possible. Great addition to the domestic economy can be achieved by recycling scrap vehicles as stated in the new laws and reusing scrap vehicles environmentally. Since 85% of the scrap car can be recycled [16]. In this study, it is potentially revealed that the end of life vehicles may create a new employment area.

The total energy consumption in the iron–steel sectors is 19% of the total energy consumption. By recycling the scrap vehicles, great energy savings can be made. These energy saving efforts have huge importance for Turkey which has an energy crisis today. In order to increase the production and decrease the costs of production, it is imperative to use energy rationally. Besides, all these energy savings have an important impact in the environmental activities that reduce emissions given out by the industrial plants and in the rational use of the solid and the liquid waste, as well [9]. Findings in this study are also complementary to the energy saving efforts.

The average per capita greenhouse gas in Turkey is far behind the OECD and EU countries. If this average is multiplied by 70 million people, Turkey becomes in the 13th rank among all those greenhouse gas producing countries. Therefore, Turkey has to fight against the climate change and should take significant steps. Although Turkey does not accept the responsibility that it will undertake by the Kyoto protocol until 2012, in the first national report it was declared that in the energy sector 11% reduction in the rate of increase could be achieved [2]. The general approach of Turkey's energy policy has been highly supply-oriented, with emphasis placed on ensuring additional energy supply to meet the growing demand, while energy efficiency has been a lower priority [1]. For this reason, Turkey's priority is to create projects for energy efficiency. In this context, it is important to use recycled metals such as iron–steel and aluminum as renewable energy resources in order to induce energy savings.

A regulation on the recycling of scrap cars has not been adopted. Draft regulations have been prepared and published in the official gazette, so in the near future it is expected to come into force. Under a regulation of recovery, these actions will contribute to the economical development by increased recovery rates of raw materials and removal of hazardous waste without harming the environment and also it will ensure to create an area of employment. It is necessary to implement the projects which should be produced quickly for the reduction of emissions and the energy consumption as mentioned in this study. Through this way it is also possible for Turkey to ensure minimum usage of ore while industrializing and protection of the natural environment as good as the case it is in the EU countries. The greatest benefit is in the emissions as well as the recovery of raw materials and also in the controlled disposal of hazardous waste in vehicles, which will all be realized provided by the recycling of scrap vehicles.

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References

[1] Kaygusuz K. Energy and environmental issues relating to greenhouse gas emissions for sustainable development in Turkey. Renewable and Sustainable Energy Reviews 2009;13:253–70.
[2] Kırcova I, Aslan IY, Katircioglu E, Kizilot S, Tas M, Altinay G, et al. Roadmap in the automotive trade, next 10 years potential, opportunities, solutions/suggestions. Istanbul: Automotive Distributors Organization (ODD); 2009 [in Turkish].
[3] Sorusbay C. Effect of carbon dioxide emissions arising from road transport on environment and controlling, UCTEA, IX. In: Automotive and industry symposium. 2005. p. 22–6 [in Turkish].
[4] Turkes M. Climate change, relations of Turkey framework convention on climate change and climate change politics. Available from: <http://www.tubitak.gov.tr/tubitak_content_files/vizyon2023/csk/EK-7.pdf> [accessed 19.08.09] [in Turkish].
[5] Ulueren M. Global warming, UN framework convention on climate change and Kyoto protocol. International Journal of Economic Issues, Ministry of Foreign Publications. Available from: <http://www.mfa.gov.tr/kuresel-isinma-bm-iklim-degisikligi-cerceve-sozlesmesi-ve-kyto-protokolu.tr.mfa>; 2001 [accessed 17.05.09] [in Turkish].
[6] http://www.geridonusum.org/haberler/ab-hurda-otomobilleri-geri-donusturecek.html [accessed 03.05.09] [in Turkish].
[7] Stefan METZLER, Pair Project TR/2004/IB/EN/01. Available from: <http://www.prtr.org/prtr/Workshops/Workshop_Inventories_Oct_2006/Presentation_20061002_METZLER_TR.pdf>; 2006 [accessed 26.06.09] [in Turkish].
[8] Bilgen S, Keles S, Kaygusuz A, Sari A, Kaygusuz K. Global warming and renewable energy sources for sustainable development: a case study in Turkey. Renewable and Sustainable Energy Reviews 2008;12:372–96.
[9] Ertem ME. The potential of energy savings in integrated iron and steel plants, UCTEA, The Chamber of Mechanical Engineers, I. National iron steel symposium and exhibition proceeding book. Ankara, Published number: E/2001/274-1; 2001: p. 1065–74 [in Turkish].

[10] Bergmann M, Schmitz A, Hayden M, Kosonen K. Imposing a unilateral carbon constraint on European energy-intensive industries and its impact on their international competitiveness—Data and analysis. European Commission, DG Economic and Financial Affairs, European Economy, economic papers, Number 298; 2007: p. 11–20.
[11] Zoraga M, Cumbul Altay M, Sivri N, Onat B, Kahruman C. Aluminum recovery and environmental effects in scrap cars. In: 4th aluminum symposium. 2009. p. 106–13 [in Turkish].
[12] UCTEA. The Chamber of Metallurgical Engineering, The Aluminum Report. Available from: <http://www.metalurji.org.tr/dergi/dergi137/d137_1445.pdf>; 2008 [accessed 18.07.09] [in Turkish].
[13] Turkish Statistical Institute, Motor Vehicle Statistics; 2007 [in Turkish].
[14] Erdemir Group Annual Report. Available from: <http://www.erdemir.com.tr/images/yatirimcilar/2008_faaliyet_raporu.pdf> [accessed 01.12.08] [in Turkish].
[15] Importance and Future of Seydisehir Aluminum Plant. Available from: <http://www.metalurji.org.tr/dergi/dergi133/d133_3033.pdf> [accessed 25.02.09] [in Turkish].
[16] The inaugural report of the Insurance Working Group of the United Nations Environment Programme Finance Initiative (UNEP FI), Insuring for Sustainability, Why and how the leaders are doing it? Available from: <http://www.unepfi.org/fileadmin/documents/insuring_for_sustainability.pdf>; May 2007 [accessed 19.08.10].